Lawrence Livermore National Laboratory

Program Update - January 2000

Laser Science & Technology

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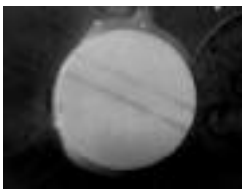
Portable Femtosecond Laser Machine Delivered to HEAF

Under the support of DOE's Stockpile Stewardship Program and DOD's Office of Munitions, we recently developed and delivered a compact, portable femtosecond laser system to the Defense and Nuclear Technologies Program (D&NT) to be used in the High Explosives Application Facility (HEAF) for precision-machining of high explosives, other energetic materials, and various weapons components.

Recent material processing experiments using short-pulse lasers have clearly demonstrated that the femtosecond laser pulses can cut materials with high precision and negligible transfer of energy (both thermal and shock) to the bulk of the object. Small quantity of high explosives (200mg pellets made of PETN, HMX, TATB or TNT, etc.) were successfully machined using a pulsed laser with 120-fs pulse duration and showed no detonation or deflagration (see Figure 1a). As a demonstration of the sensitivity to pulse-duration we also tried cutting with 500-ps laser pulses. Bulk heating is anticipated in this case because the pulse-duration is significantly longer than the time needed for transferring energy between electrons and phonons which is about 10-ps in dielectrics. As shown in Figure 1b, the heat deposited by the 500-ps pulses fueled an intense burn of the HE pellet.



HE pellet cut with fs lasers pulses

HE pellet cut with ps pulses

The HEAF laser-cutting machine is very compact and fully automated, and can be operated by personnel with little laser expertise. The machine is mounted on a portable 4'x10' optical table which can be rolled inside the HEAF facility for various scale of experiments. The overall system consists of a short-pulse Ti: sapphire laser, beam positioning and power control equipment. It has an average output of 5 W (1.4 mJ @ 3.5 kHz, 120 fs pulse-duration), with a capability to increase to 20-25 W when additional power-amplifiers and pump lasers are installed. Instead of an arc-lamp-pumped pump laser as in the system delivered to Y12, the system incorporates a frequency-doubled, diode-pumped solid-state laser as pump source. Diode pumping improves the machine maintenance interval from every three weeks (required for the lamp-pumped systems) to over one year. Activation of the laser system in HEAF is currently underway.

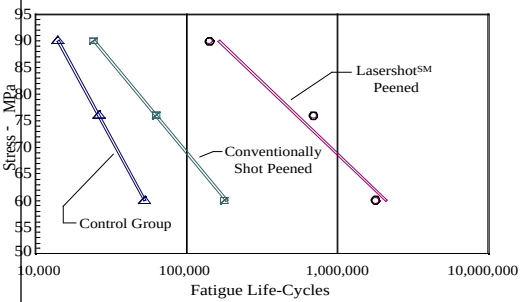
Lasershot℠ Peening Improves Service Life of Metal Parts

In a collaborative effort with the Metal Improvement Co. Inc, we are evaluating the effectiveness of Lasershot℠ peening in extending the service life of metal components for industrial and government application. Using a kilowatt-class, 100 J/pulse, Nd:doped glass laser, we were able to rapidly treat the surfaces of metal components and induce deep compressive stress to significantly extend their service life.

By optimizing the process parameters such as laser pulse duration (10-to-30 ns), fluence, intensity (100-to-300 J/cm^2) and number of treatment pulses, we have treated a broad range of materials including aluminum, titanium, nickel and steel-based alloys. Since fatigue cracks on metal components typically develop at the surface; deep compressive stress can prevent their initiation and growth and consequently improve component lifetime. Test results have shown deep compressive stress on the work piece extending to depths of 0.1 inches. As shown in the figure below, recent fatigue tests on 2024 T3 aluminum, under various stress load conditions, show more than 50 times improvement in fatigue lifetime for structural aluminum test plates when compared to conventional shot peening.

Lasershot℠ peening could be used to extend the service lifetime of many critical parts from jet-engine fan blades, F-16 bulkheads to hip joints. One application recently identified for DOE's Civilian Radioactive Waste Management System (CRWMS) Program is to improve the service lifetime of metal canisters, designed for long-term disposal of high-level radioactive waste (generated by commercial nuclear power plants and government reactors) potentially at Yucca Mountain in Nevada, which will be discussed in a future Update issue.

Comparison -Laser peening versus conventional shot peening on Laser drilled holes in aluminum



Fatigue Life-Cycle Measured in Aluminum

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